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Navy DDG-1000 Destroyer Program: Background, Oversight Issues, and Options for Congress

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Navy DDG-1000 Destroyer Program: Background, Oversight Issues, and Options for Congress

Summary

The Navy is procuring a new kind of destroyer called the DDG-1000. The ship was earlier called the DD(X). Navy plans call for procuring a total of seven DDG-1000s. The first two were procured in FY2007 using split funding (i.e., incremental funding) in FY2007 and FY2008. The Navy estimates their combined procurement cost at $6,325 million. This figure includes about $2.0 billion detailed design/non-recurring engineering (DD/NRE) costs for the entire DDG-1000 class.

The Navy wants to procure the third DDG-1000 in FY2009; the Navy estimates its procurement cost at $2,653 million. The ship received $150 million in advance procurement funding in FY2008, and the Navy's proposed FY2009 budget requests the remaining $2,503 million. The Navy's proposed FY2009 budget also requests $51 million in advance procurement funding for the fourth DDG-1000, which the Navy wants to procure in FY2010.

At a February 27, 2008, hearing on Navy shipbuilding programs before the Defense subcommittee of the House Appropriations Committee, the chairman of the subcommittee, Representative John Murtha, stated that the subcommittee is considering deferring procurement of the third DDG-1000 and using the funding programmed for that ship to instead procure three other ships for the Navy in FY2009 — a San Antonio (LPD-17) class amphibious ship and two Lewis and Clark (TAKE-1) class dry cargo ships.

At a March 6, 2008, hearing on the Department of the Navy's proposed FY2009 budget before the House Armed Services Committee, certain committee members, including Representative Gene Taylor, the chairman of the Seapower and Expeditionary Forces subcommittee, stated that they are considering the option of not procuring additional DDG-1000s and instead procuring additional Arleigh Burke (DDG-51) class Aegis destroyers. These DDG-51s, it was stated at the hearing, could act as a bridge to a design for the Navy's planned CG(X) cruiser that is based on an enlarged version of the DDG-51 hull and powered by one-half of the reactor plant that the Navy has designed for its new Ford (CVN-78) class nuclear-powered aircraft carriers.

The DDG-1000 program raises several potential oversight issues for Congress, including the accuracy of Navy cost estimates for the program, program affordability and cost effectiveness, technical risk, and the program's potential implications for the shipbuilding industrial base.

Congress has several options regarding the DDG-1000 program, including the options mentioned at the February 27 and March 6, 2008, hearings. This report will be updated as events warrant.

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[1] Source: Transcript of spoken remarks of Representative Murtha at the hearing. See also, for example, Dan Taylor, "Murtha Mulls Cutting DDG-1000, Adding Two T-AKE Ships and 10th LPD-17," *Inside the Navy*, March 3, 2008, and Ashley Roque, "Murtha, Young Press Navy on Shipbuilding Plan, Look to Alter 2009 Budget," *CongressNow*, February 27, 2008.

plant that the Navy has designed for its new Ford (CVN-78) class nuclear-powered aircraft carriers.[2]

The issue for Congress is whether to approve, modify, or reject the Navy's proposals for the DDG-1000 program. Decisions that Congress makes on procurement of surface combatants will significantly affect future Navy capabilities, Navy funding requirements, and the shipbuilding industrial base.

Background

DDG-1000 Program

Origin of Program. The program known today as the DDG-1000 program was announced on November 1, 2001, when the Navy stated that it was replacing a destroyer-development effort called the DD-21 program, which the Navy had initiated in the mid-1990s, with a new Future Surface Combatant Program aimed at developing and acquiring a family of three new classes of surface combatants:[3]

- **a destroyer called DD(X)** for the precision long-range strike and naval gunfire mission,
- **a cruiser called CG(X)** for the air defense and ballistic missile mission,[4] and
- **a smaller combatant called the Littoral Combat Ship (LCS)** to counter submarines, small surface attack craft (also called "swarm boats") and mines in heavily contested littoral (near-shore) areas.[5]

On April 7, 2006, the Navy announced that it had redesignated the DD(X) program as the DDG-1000 program. The Navy also confirmed in that announcement

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[2] Source: Transcript of spoken remarks of Representatives Gene Taylor and Jim Saxton at the hearing.

[3] The DD-21 program was part of a Navy surface combatant acquisition effort begun in the mid-1990s and called the SC-21 (Surface Combatant for the 21st Century) program. The SC-21 program envisaged a new destroyer called DD-21 and a new cruiser called CG-21. When the Navy announced the Future Surface Combatant Program in 2001, development work on the DD-21 had been underway for several years, while the start of development work on the CG-21 was still years in the future. The current DDG-1000 destroyer CG(X) cruiser programs can be viewed as the descendants, respectively, of the DD-21 and CG-21. The acronym SC-21 is still used in the Navy's research and development account to designate the line item (i.e., program element) that funds development work on both the DDG-1000 and CG(X).

[4] For more on the CG(X) program, see CRS Report RL34179, *Navy CG(X) Cruiser Program: Background, Oversight Issues, and Options for Congress,* by Ronald O'Rourke.

[5] For more on the LCS program, see CRS Report RL33741, *Navy Littoral Combat Ship (LCS) Program: Oversight Issues and Options for Congress,* by Ronald O'Rourke.

that the first ship in the class, DDG-1000, is to be named the Zumwalt, in honor of Admiral Elmo R. Zumwalt, the Chief of Naval operations from 1970 to 1974. The decision to name the first ship after Zumwalt was made by the Clinton Administration in July 2000, when the program was still called the DD-21 program.[6]

Planned Surface Combatant Force Structure. The Navy in coming years wants to achieve and maintain a fleet of 313 ships, including 88 cruisers and destroyers and 55 LCSs.[7] The 88 cruisers and destroyers are to include 7 DDG-1000s, 19 CG(X) cruisers, and 62 older Arleigh Burke (DDG-51) class Aegis destroyers.[8]

Planned DDG-1000 Procurement Through FY2013. **Table 1** shows actual and planned procurement of DDG-1000s in the FY2009-FY2013 Future Years Defense Plan (FYDP). As shown in the table, the Navy plans to procure all 7 DDG-1000s by the end of the FYDP. The Navy originally envisaged procuring a total of 16 to 24 DDG-1000s. Navy officials subsequently testified in February and March 2005 that they had a requirement for 8 to 12. The Navy's 313-ship plan, announced in February 2006, reduced the planned total to 7.

Table 1. Actual and Planned DDG-1000 Procurement

	FY07	FY08	FY09	FY10	FY11	FY12	FY13
DDG-1000	2[a]	0[a]	1	1	1	1	1

Source: FY2009-FY2013 Future Years Defense Plan (FYDP).
a. Two DDG-1000s procured in FY2007 using split funding across FY2007 and FY2008.

Ship Missions and Design Features. The DDG-1000 program is essentially a restructured continuation of the earlier DD-21 program, and the DDG-1000 will resemble the DD-21 in terms of mission orientation and ship design: The DDG-1000 is to be a multimission ship with an emphasis on land-attack operations, reflecting a Navy desire to replace the large-caliber naval gunfire support capability that the Navy lost in 1990-1992, when it removed its four reactivated Iowa-class battleships from service.

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[6] For more on Navy ship names, see CRS Report RS22478, *Navy Ship Names: Background For Congress*, by Ronald O'Rourke.

[7] For more on the proposed 313-ship fleet, see CRS Report RL32665, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*, by Ronald O'Rourke.

[8] The Navy's 62 DDG-51s were procured between FY1985 and FY2005. The first entered service in 1991. By the end of FY2006, 49 had entered service and the remaining 13 were in various stages of construction, with the final ships scheduled to be delivered in 2010 or 2011. The Navy plans to give DDG-51s a mid-life modernization and operate them to age 35. (See CRS Report RS22595, *Navy Aegis Cruiser and Destroyer Modernization: Background and Issues for Congress*, by Ronald O'Rourke.) The DDG-51s, which displace about 9,200 tons, are equipped with the Aegis combat system and are therefore referred to as Aegis destroyers.

The DDG-1000 is to have a reduced-size crew (compared to the Navy's current destroyers and cruisers) of 148 sailors so as to permit reduced operating and support (O&S) costs. The ship is to incorporate a significant number of new technologies, including a wave-piercing, tumblehome hull design for reduced detectability, a superstructure made partly of large sections of composite materials rather than steel or aluminum, an integrated electric-drive propulsion system, a total-ship computing system for moving information about the ship, automation technologies for the reduced-sized crew, a dual-band radar, a new kind of vertical launch system (VLS) for storing and firing missiles, and two copies of a 155mm gun called the Advanced Gun System (AGS).

With a full load displacement of 14,987 tons, the DDG-1000 design is roughly 50% larger than the Navy's current 9,500-ton Aegis cruisers and destroyers, and larger than any Navy destroyer or cruiser since the nuclear-powered cruiser Long Beach (CGN-9), which was procured in FY1957.

Program Funding. **Table 2** shows DDG-1000 funding through FY2013. The table excludes about $1.1 billion in research and development funding provided for the predecessor DD-21 program from FY1995 through FY2001. Additional funding for research and development and for outfitting and post-delivery costs is programmed for the DDG-1000 program after FY2013. The table also excludes $513 million in post-FY2013 outfitting and post-delivery costs.

As can be seen in the table, the Navy is requesting $449 million in FY2009 research and development funding for the DDG-1000 program. This $449 million is included within $679 million that the Navy is requesting in FY2009 for a line item (i.e., program element, or PE) in the Navy's research and development account called "DDG-1000 Total Ship System Engineering" (PE0604300N, the 100th line item in the account). This line item was previously called "SC-21 Total Ship System Engineering." Although this line item is named for the DDG-1000 program, it includes research and development funding for both the DDG-1000 and CG(X) programs. The other $230 million requested in this line item is for the CG(X) program.[9]

Based on the figures in the table, when $1.1 billion in FY1995-FY2001 DD-21/DD(X) research and development costs and $513 million in post-FY2013 outfitting and post-delivery costs are included, the Navy estimates the total acquisition (i.e., development plus procurement) cost of the seven-ship DDG-1000 program at about $28.9 billion in then-year dollars, or an average of about $4.1 billion per ship, not including additional DDG-1000 research and development costs after FY2013.

Several major technologies developed for the DDG-1000 are to be used on the CG(X) cruiser and other future Navy ships, so at least some portion of the DDG-1000

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[9] As discussed in a previous footnote, SC-21 means surface combatant for the 21st Century and refers to the Navy's pre-November 2001 SC-21 program to develop a destroyer called the DD-21 (now called the DDG-1000) and an eventual cruiser called the CG-21 (now called CG(X)).

program's research and development costs might be viewed as not truly specific to the DDG-1000 program. Based on the figures in the table, when the DDG-1000 program's research and development costs are excluded, the Navy estimates the total procurement cost of the DDG-1000 program (including $513 million in post-FY2013 outfitting and post-delivery costs) at about $19.9 billion in then-year dollars, or an average of about $2.8 billion per ship.

Table 2. DDG-1000 Program Funding, FY2002-FY2013

(millions of then-year dollars, rounded to nearest million)

	FY02 thru FY06	FY 07	FY08	FY09	FY10	FY11	FY12	FY13	Total thru FY13
Research, Development, Test and Evaluation, Navy (RDTEN) account									
DDG-1000[a]	4548	773	514	449	520	565	326	174	7869
Shipbuilding and Conversion, Navy (SCN) account									
DDG-1000 and DDG-1001	1010	2557	2757	0	0	0	0	0	6325
DDG-1002	0	0	150	2503	0	0	0	0	2653
DDG-1003	0	0	0	51	2663	0	0	0	2714
DDG-1004	0	0	0	0	51	2377	0	0	2428
DDG-1005	0	0	0	0	0	50	2569	0	2619
DDG-1006	0	0	0	0	0	0	50	2347	2397
Outfitting/post-delivery costs[b]	0	0	0	0	16	61	87	132	295
Subtotal SCN	1010	2557	2907	2554	2730	2488	2706	2479	19431
TOTAL	**5558**	**3330**	**3421**	**3003**	**3250**	**3053**	**3032**	**2653**	**27300**

Sources: Prepared by CRS based on Navy FY2009 budget submission of February 2008 and (for FY2002-FY2006) RDTEN costs) Navy Office of Legislative Affairs data provided to CRS on March 28, 2007. Figures may not add due to rounding.

a. DDG-1000 portion of Program Element (PE) 0604300N, DDG-1000 Total Ship System Engineering (previously called SC-21 Total Ship System Engineering). PE0604300N also includes funding the CG(X) cruiser program. Figures shown do not include $1,111.4 million in RDTEN funding provided for DD-21/DD(X) program in FY1995-FY2001. Additional RDTEN funding for the DDG-1000 program required after FY2013. The Navy states that figure for RDTEN for FY2002-FY2006 does not include congressional adds to PE0604300N during that period; budget-justification documents show about $41 million in such additional funding in FY2006 and much smaller amounts in FY2002-FY2005.

b. $513 million in additional outfitting/post-delivery costs programmed after FY2013.

Acquisition Strategy.

Navy Management. Since September 30, 2005, the Navy has managed the DDG-1000 program through a series of separate contracts with major DDG-1000 contractors, including Northrop Grumman Shipbuilding (NGSB), General Dynamics Bath Iron Works (GD/BIW), Raytheon, and BAE Systems (the maker of the AGS).

Under this arrangement, the Navy is acting as the overall system integrator for the program.

Earlier Proposal for Winner-Take-All Acquisition Strategy. Under a DDG-1000 acquisition strategy approved by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L) on February 24, 2004, the first DDG-1000 was to have been built by NGSB, the second ship was to have been built by GD/BIW, and contracts for building the first six were to have been equally divided between NGSB and GD/BIW.

In February 2005, Navy officials announced that they would seek approval from USD AT&L to instead hold a one-time, winner-take-all competition between NGSB and GD/BIW to build all DDG-1000s. On April 20, 2005, the USD AT&L issued a decision memorandum deferring this proposal, stating in part, "at this time, I consider it premature to change the shipbuilder portion of the acquisition strategy which I approved on February 24, 2004."

Several Members of Congress also expressed opposition to Navy's proposal for a winner-take-all competition. Congress included a provision (Section 1019) in the Emergency Supplemental Appropriations Act for 2005 (H.R. 1268/P.L. 109-13 of May 11, 2005) prohibiting a winner-take-all competition. The provision effectively required the participation of at least one additional shipyard in the program but did not specify the share of the program that is to go to the additional shipyard.

On May 25, 2005, the Navy announced that, in light of Section 1019 of P.L. 109-13, it wanted to shift to a "dual-lead-ship" acquisition strategy, under which two DDG-1000s would be procured in FY2007, with one to be designed and built by NGSB and the other by GD/BIW.

Section 125 of the FY2006 defense authorization act (H.R. 1815/P.L. 109-163) again prohibited the Navy from using a winner-take-all acquisition strategy for procuring its next-generation destroyer. The provision again effectively requires the participation of at least one additional shipyard in the program but does not specify the share of the program that is to go to the additional shipyard.

Milestone B Approval for Dual-Lead-Ship Strategy. On November 23, 2005, the USD AT&L, granted Milestone B approval for the DDG-1000, permitting the program to enter the System Development and Demonstration (SDD) phase. As part of this decision, the USD AT&L approved the Navy's proposed dual-lead-ship acquisition strategy and a low rate initial production quantity of eight ships (one more than the Navy currently plans to procure).

Construction Sequence for Two Lead Ships. Until July 2007, it was expected that NGSB would be the final-assembly yard for the first DDG-1000 and that GD/BIW would be the final-assembly yard for the second. On July 17 and 18, 2007, it was reported that the Navy was considering the option of instead assigning the first ship to GD/BIW and the second to NGSB. The potential switch in construction sequence reportedly was being considered by the Navy in part because the Navy believed it could provide some additional help in maintaining GD/BIW's work force as its DDG-51-related construction work winds down, and because it

could also provide some additional time for NGSB to recover from Katrina-related damage.[10] On September 25, 2007, the Navy announced that it had decided to build the first DDG-1000 at GD/BIW, and the second at NGSB.[11] The difference in the two ships' construction schedules (about one year) is driven in large part by the production capacities of vendors making certain components for the ships — some of these vendors can make only one ship-set worth of components at a time.

Contract Modification Awards for Two Lead Ships. On February 14, 2008, the Navy awarded contract modifications to GD/BIW and NGSB for the construction of the two lead ships. The awards were modifications to existing contracts that the Navy has with GD/BIW and NGSB for detailed design and construction of the two lead ships. Under the modified contracts, the line item for the construction of the dual lead ships is treated as a cost plus incentive fee (CPIF) item.

Acquisition Strategy for Third and Subsequent Ships.[12] Under an acquisition strategy approved by the DOD acquisition executive and documented in an updated Acquisition Strategy Report (ASR) of February 13, 2008, the Navy intends to conduct a single competition between GD/BIW and NGSB for the contracts to build the five remaining ships in the program (i.e., ships three through seven). The winner of the competition would build three ships (the third, fifth, and seventh ships in the program, to be procured in FY2009, FY2011, and FY2013, respectively), while the other firm would build two ships (the fourth and sixth ships in the program, to be procured in FY2010 and FY2012, respectively).

Under this strategy, each firm would build a minimum of two ships, and the two firms would in effect compete for the right to build the remaining fifth ship. In light of the shared production arrangement for the DDG-1000 program (see discussion below), the two firms more specifically would be competing for the right to build certain portions of that fifth ship, and to perform the final-assembly work on that ship — work that would amount to about 50% of the total shipyard labor hours needed to build that fifth ship. The two firms could also be viewed as competing for the timing of their respective second ships, as the winner's second ship would be the ship to be procured in FY2009, while the other firm's second ship would be the ship to be procured in FY2010.

The Navy intends to structure the contract with the winning firm as a fixed-price incentive fee (FPIF) contract to build the ship to be procured in FY2009, with priced options for building the ships to be procured in FY2011 and FY2013. The Navy

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[10] Christopher P. Cavas, "First DDG 1000 Could Shift To Bath," *Defense News*, July 17, 2007; Geoff Fein, "Navy Exploring Workload Options For DDG-1000," *Defense Daily*, July 18, 2007.

[11] Geoff Fein, "Bath Iron Works To Take Delivery of First Set of DDG-1000 Equipment," *Defense Daily*, September 26, 2007; Christopher P. Cavas, "Bath To Build First DDG 1000," *DefenseNews.com*, October 1, 2007; and Chris Johnson, "Navy Changes Equipment Delivery For First Two DDG-1000 Destroyers," *Inside the Navy*, October 1, 2007.

[12] The information presented in this section is taken based on an April 10, 2008, Navy briefing to CRS and CBO on the DDG-1000 program.

intends to structure the contract with the other firm as an FPIF contract to build the ship to be procured in FY2010, with a priced option to build the ship to be procured in FY2012. If one or more of the third and subsequent ships are not procured in the years in which the Navy currently plans procure them, the options would not be exercised and the Navy might conduct a new competition to determine who would build the follow-on ships in the program.

Shared Production Arrangement. NGSB and GD/BIW have agreed on a shared-production arrangement for building DDG-1000s. Under this arrangement, certain parts of each ship will be built by NGSB, certain other parts of each ship will be built by GD/BIW, and the remaining parts of each ship would be built by the yard that does final-assembly work on that ship. Each firm's repeating portion of the ship would amount to about 25% of the labor hours for the ship; the yard that does the final-assembly work on the ship would also perform the remaining 50% or so of the labor hours needed to build the ship. The arrangement can be viewed as somewhat analogous to the joint-production arrangement for Virginia-class submarines that was proposed by industry and the Navy, and then approved by Congress in Section 121 of the FY1998 defense authorization act (H.R. 1119/P.L. 105-85 of November 18, 1997).[13]

Procurement Cost Cap. Section 123 of the FY2006 defense authorization act (H.R. 1815/P.L. 109-163 of January 6, 2006), limits the procurement cost of the fifth DDG-1000 to $2.3 billion, plus adjustments for inflation and other factors.

Surface Combatant Industrial Base

All cruisers, destroyers, and frigates procured since FY1985 have been built at two shipyards — General Dynamics' Bath Iron Works (GD/BIW) in Bath, ME, and the Ingalls shipyard in Pascagoula, MS, that forms part of NGSB.[14] Both yards have long histories of building larger surface combatants. Construction of Navy surface combatants in recent years has accounted for virtually all of GD/BIW's ship-construction work and for a significant share of Ingalls' ship-construction work. Navy surface combatants are overhauled, repaired, and modernized at GD/BIW, NGSB, other private-sector U.S. shipyards, and government-operated naval shipyards (NSYs).

Lockheed Martin and Raytheon are generally considered the two leading Navy surface ship radar makers and combat system integrators. Boeing is another system integrator and maker of Navy surface ship weapons and equipment.

The surface combatant industrial and technological base also includes hundreds of additional firms that supply materials and components. The financial health of the

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[13] For more on the Virginia-class joint-production arrangement, see CRS Report RL32418, *Navy Attack Submarine Force-Level Goal and Procurement Rate: Background and Issues for Congress*, by Ronald O'Rourke.

[14] NGSB also includes the Avondale shipyard near New Orleans, Newport News Shipbuilding of Newport News, VA, and a fourth facility at Gulfport, MS.

supplier firms has been a matter of concern in recent years, particularly since some of them are the sole sources for what they make for Navy surface combatants.

Oversight Issues for Congress

Accuracy of Navy Cost Estimate

CBO March 2008 Estimate. The Congressional Budget Office (CBO) believes that the Navy is significantly underestimating DDG-1000 procurement costs. CBO testified in March 2008 that it believes the first two DDG-1000s will each cost about 56% more than the Navy estimates, that the other five ships in the program would each cost about 64% more than the Navy estimates, and that the complete seven-ship class consequently would cost about 60% more than the Navy estimates. CBO stated that:

> The [Navy's FY]2009 budget suggests that the Navy expects the first two [DDG-1000s] to cost $3.2 billion each [in constant FY2009 dollars] and the following five to cost an average of $2.2 billion each [in constant FY2009 dollars], which is a cost increase of about $200 million [in constant FY2009 dollars] per ship for the last five ships compared with the cost in the Navy's 2008 budget. CBO, by contrast, estimates that the first two DDG-1000s would cost $5.0 billion apiece [in constant FY2009 dollars], and the next five would cost an average of $3.6 billion each [in constant FY2009 dollars].
>
> The Navy's estimate for the two lead-ship DDG-1000s prices the ship at about $250 million (in 2009 dollars) per thousand tons of lightship displacement, which is the weight of the ship minus its crew, fuel, ammunition, and stores. In comparison, the lead ship of the DDG-51 class destroyer cost about $390 million per thousand tons, and the lead ship of the Ticonderoga class cruiser cost more than $400 million per thousand tons.... CBO uses the DDG-51 lead-ship cost as its basis for estimating the cost of the lead ship of the DDG-1000 class, adjusting for the size of the ship.
>
> The Navy has asserted that the basis for CBO's estimate may not be valid because the DDG-51 had a number of problems in the early stages of its construction that should not be expected to occur during the construction of the first DDG-1000s. In particular, the design of the lead DDG-51 was disrupted and delayed because a new design tool being used at the time was incomplete and not well understood. It had to be abandoned and the design restarted using more traditional methods. The design of the lead DDG-51 was thus about 20 percent complete when construction began. In comparison, according to the Navy, the design of the DDG-1000 is progressing far more smoothly; the Navy expects to have the design 85 percent complete when construction begins this summer. In addition, the DDG-51 is a smaller, more densely built ship and, therefore, the Navy believes that on a ton-for-ton basis, it has been more difficult to build than the DDG-1000 class is going to be.
>
> Although the Navy may not encounter the same problems constructing the lead DDG-1000s as the service did in constructing the lead DDG-51, it is CBO's view that the Navy is likely to encounter other problems that will increase the costs of the DDG-1000 and delay its construction. As Navy officials have stated,

> lead ships are often very difficult to build and typically have many problems in construction. The problems with the first littoral combat ships (for which costs doubled) and the lead ship of the LPD-17 class amphibious transport dock (for which costs increased by 80 percent and construction time more than doubled) illustrate the difficulties the Navy has encountered recently in constructing lead ships. Both the LCS and the LPD-17 are much less complex technologically than the DDG-1000 will be. And Navy officials have stated that the Virginia class submarine program was about at the same point in its design as the DDG-1000 will be when construction of those new submarines began. Nevertheless, the cost of the first two ships of the Virginia class exceeded their budget by an average of 17 percent. Moreover, the DDG-1000 program is incorporating 10 major new technologies into the lead ship of the class compared with the technologies used in the previous-generation DDG-51 destroyer.... In the past, the Navy typically introduced three or four major new technologies into a new class of surface combatant.
>
> Comparing the Navy's estimate for two additional DDG-51s and the Navy's estimatefor the seventh DDG-1000 to be purchased in 2013 illustrates the risk for cost growth in the latter program. Last year, the Navy stated that if the Congress authorized and bought two new DDG-51s in 2008 — ships that would have the benefit of substantial efficiencies and lessons learned because of the 62 ships that were built previously — the cost would have been between $3.1 billion and $3.2 billion, or about $1.6 billion apiece in 2009 dollars. At the same time, in its fiscal year 2009 budget submission to the Congress, the Navy stated that the cost to build the seventh DDG-1000 in 2013 will be about $2.4 billion in 2013 dollars. Deflating the cost of the seventh DDG-1000, using the inflation index provided to CBO by the Navy for shipbuilding, brings the Navy's estimate for that ship to about $1.9 billion in 2009 dollars. The lightship displacement of the DDG-1000 is about 5,000 tons (or more than 50 percent) greater than the lightship displacement of the DDG-51s under construction today. In effect, the Navy's estimates imply that those 5,000 extra tons, as well as the 10 new technologies being incorporated into the DDG-1000 class, will add only 15 percent, or about $300 million, to the ship's cost.[15]

CBO also testified in March 2008 that:

> The relatively simple design of the LCSs and the substantial cost increases that have occurred in the program suggest that the Navy may also have trouble meeting its cost targets for the larger, much more complex surface combatants in its shipbuilding plan, such as the DDG-1000 and the CG(X).[16]

GAO July 2007 Testimony. Although the Navy publicly stands by its DDG-1000 cost estimates, the Government Accountability Office (GAO) testified in July 2007 that the Navy had assigned a confidence level of about 45% to its own estimates, meaning that the Navy itself believed there was about a 55% chance that DDG-1000s will exceed the Navy's estimates. GAO testified that:

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[15] Statement of Eric J. Labs, Senior Analyst, [on] Current and Projected Navy Shipbuilding Programs, before the Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, U.S. House of Representatives, July 24, 2007, pp. 18-20.

[16] Ibid, p. 24.

> One way to improve the cost-estimating process is to present a confidence level for each estimate, based on risk and uncertainty analyses. By conducting an uncertainty analysis that measures the probability of cost growth, the Navy can identify a level of confidence for its estimates and determine whether program costs are realistically achievable. Navy cost analysts told us that they used quantitative risk analyses to test the validity of cost estimates of CVN 78 and DDG 1000. We believe that the Navy and the Department of Defense (DOD) should take this a step further — requiring a high confidence level threshold when making program commitments and budget requests. The Defense Acquisition Performance Assessment Panel recommended an 80 percent confidence level, meaning that a program has an 80 percent chance of achieving its estimated costs. Whether this is the right level warrants thoughtful discussion, but it is worth noting that analyses for CVN 78 and DDG 1000 were well below an 80 percent confidence level (in the case of DDG 1000 at around 45 percent) — increasing the likelihood that costs will grow above budget.[17]

GAO's July 2007 testimony was presented while Congress was considering the Navy's proposed FY2008 budget. In its proposed FY2009 budget, the Navy has increased its estimate of DDG-1000 procurement costs by about 6.9%.[18] In light of this increase, it is possible that the Navy's confidence level has increased from 45% to some higher figure.

October 2007 Report on CAIG Estimate. On October 1, 2007, it was reported that the Cost Analysis Improvement Group (CAIG), a cost-estimating office within the Office of the Secretary of Defense, had estimated that the first two DDG-1000s would together cost about $7.2 billion to procure, or about 14% more than the Navy's combined estimate for the two ships in 2007.[19]

March 2008 CRS Testimony on Potential Impact of Cost Growth. Using CBO's cost estimates for the DDG-1000 program, CRS testified in March 2008 on the question of the potential implications for the Navy's shipbuilding program of cost growth in the DDG-1000 program. CRS stated that:

> Under CBO's estimates, the first two DDG-1000s, instead of having a combined cost of about $6.3 billion in then-year dollars, as the Navy now estimates, might have a combined cost of roughly $10.2 billion in then-year dollars, which would be an increase of roughly $3.9 billion in then-year dollars. The remaining five ships in the class, instead of having a combined procurement

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[17] Government Accountability Office, *Defense Acquisitions[:] Realistic Business Cases Needed to Execute Navy Shipbuilding Programs, Statement of Paul L. Francis, Director, Acquisition and Sourcing Management Team, Testimony Before the Subcommittee on Seapower and Expeditionary Forces, Committee on Armed Services, House of Representatives,* July 24, 2007 (GAO-07-943T), pp. 17-18.

[18] Under the FY2008 shipbuilding plan, the Navy estimated the combined end cost of the seven DDG-1000s at $18,185 million in then-year dollars; under the FY2009 shipbuilding plan, the Navy estimates their combined end cost at $19,136 million in then-year dollars. There is no change in the years in which the ships are to be procured.

[19] "Sticker Price," *Defense Daily,* October 1, 2007. See also Christopher P. Cavas, "DDG 1000 Contract Talks Hit Rough Seas," *DefenseNews.com,* October 15, 2007, which refers to "a recent non-Navy estimate" of $7.2 billion for the two ships.

> cost of about $12.8 billion in then-year dollars, as the Navy now estimates, might have a combined procurement cost of roughly $20.7 billion in then-year dollars, which would be an increase of roughly $7.9 billion in then-year dollars. Under CBO's estimates, the combined cost growth for all seven ships would be roughly $11.8 billion in then-year dollars, which is a figure roughly comparable to the total amount of funding in Shipbuilding and Conversion, Navy (SCN) appropriation account in certain recent years.[20]

Program Affordability and Cost Effectiveness

The issue of the affordability and cost-effectiveness of the DDG-1000 program has been debated in Congress at various times in the past. The debate has often focused on comparing the costs and capabilities of the DDG-1000 and DDG-51 designs.

The Navy has testified in 2008 that a single additional DDG-51 might cost about $2.1 billion to procure in FY2009, and that two additional DDG-51s might require about $3.3 billion to procure in FY2009.[21]

The DDG-1000 and DDG-51 are both multimission destroyers, but they have somewhat different mission emphases. The DDG-1000 design features a stronger emphasis on land-attack operations and operations in littoral waters. The DDG-51 design is more oriented toward blue-water operations. Consistent with its larger size, higher procurement cost, and greater use of new technologies, the Navy believes the DDG-1000 is more capable than the DDG-51 design in several respects. For detailed information on the capabilities of the DDG-1000 and DDG-51 designs, see **Appendix B**.

In assessing issue of the affordability and cost-effectiveness of the DDG-1000 program, a key question for Congress is: What are the military capability gaps that need to be filled through procurement of destroyers over the next few years, and which general procurement approach for filling those gaps — procurement of DDG-1000s, procurement of DDG-51s, or some other approach — would be the best in terms of affordability and cost effectiveness?

July 19-20, 2005 Hearing. The affordability and cost-effectiveness of the DDG-1000 program was explored extensively at a two-part hearing on the DDG-1000 program held on July 19 and 20, 2005, before the Projection Forces subcommittee of the House Armed Services Committee. At the end of the July 19 portion of the hearing, Department of Defense (DOD) and Navy witnesses were asked by the subcommittee chairman, Representative Roscoe Bartlett, to provide the subcommittee with their own individual views on the procurement cost figures at

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[20] Statement of Ronald O'Rourke, Specialist in Naval Affairs, Congressional Research Service, Before the House Armed Services Committee, Subcommittee on Seapower and Expeditionary Forces Hearing on The Navy Shipbuilding Budget Request, March 14, 2008, p. 9.

[21] Source: Spoken testimony of Navy officials at April 8, 2008, hearing before the Seapower subcommittee of the Senate Armed Services Committee.

which the lead DDG-1000 and a follow-on DDG-1000 (defined as the fifth ship) would become unaffordable. At the beginning of the July 20 portion of the hearing, Representative Bartlett stated that the figures provided by the witnesses ranged from $4 billion to $4.5 billion for the lead ship and $2.5 billion to $2.9 billion for the fifth ship. The Navy's current cost estimates for the first and fifth DDG-1000s are below these figures; CBO's current cost estimates for the first and fifth DDG-1000s are substantially above these figures.

Arguments of DDG-1000 Supporters. The Navy and others who argue that the DDG-1000 is affordable and cost effective make the following points, among others:

- Although the DDG-1000 design is more expensive to procure than the DDG-51 design, it is much more capable than the DDG-51 design in many respects, making it more cost-effective than the DDG-51 design.

- The DDG-1000 design is optimized for operations in littoral (near-shore) waters, while the DDG-51 design is optimized for blue-water operations farther from shore. The Navy has ample blue-water warfighting capability, but needs to improve its littoral warfighting capability. The Navy does not require additional DDG-51s.

- Within the area of littoral-warfare capabilities, a key Navy need is to improve the fleet's naval surface fire support (NSFS) capabilities. The DDG-1000, with its two AGSs, was designed with this need in mind and has much more NSFS capability than the DDG-1000 design.

- A DDG-1000, with a crew of 148 (about half the size of a DDG-51's crew), will have only about one-half the life-cycle crew-related costs of a DDG-51. Crew-related costs are a major component of a ship's total life-cycle operating and support (O&S) costs. The lower life-cycle crew-related costs of the DDG-1000 design compared to those of the DDG-51 design enhance the DDG-1000 design's cost-effectiveness relative to the DDG-51 design.

- Building additional DDG-1000s would keep open the production line for the DDG-1000 hull design, which could form the basis for the design of the Navy's planned CG(X) cruiser. Past Navy testimony has indicated a Navy preference for basing the CG(X), if possible, on the DDG-1000 hull design, so as to reduce CG(X) hull design costs and take maximum advantage of DDG-1000 production learning curve benefits. Procuring additional DDG-51s would pose some production-line uncertainties regarding DDG-51 sub-vendors.

Arguments of DDG-1000 Skeptics or DDG-51 Supporters. Skeptics of continued procurement of DDG-1000s, or supporters of procuring additional DDG-51s instead of additional DDG-1000s, might argue the following:

- The DDG-1000's capability improvements, though significant, are not worth the ship's cost, particularly if the ship's cost turns out to be closer to CBO's estimates than to the Navy's estimates. Actual DDG-51 production costs are fairly well understood as a result of many prior years of production, while actual DDG-1000 production costs are unknown. As a consequence, procuring DDG-51s would pose less risk in terms of potential cost overruns than procuring DDG-1000s.

- Many of the DDG-1000's capability improvements, though significant, might not be needed to address critical military capability gaps. The DDG-1000's capabilities reflect insufficient discipline on the Navy's part in establishing mission requirements for the DDG-1000. (For a discussion of DDG-1000 mission requirements, see **Appendix A**.) Although the Navy states that it does not require additional DDG-51s, the Navy would find good uses for them. The Navy might discover in coming years that it needs additional Aegis-equipped ships to perform the Navy's emerging mission of ballistic missile defense.

- If the DDG-1000's most-needed contribution to military capabilities is the improved NSFS capability provided by the ship's two AGSs, then the DDG-1000 design represents a very expensive way to add this capability to the fleet. AGSs can be added to the fleet less expensively by building a modified version of the LPD-17 amphibious ship hull equipped with two AGSs. (For a discussion of potential lower-cost ship designs, see **Appendix C**.)

- Crew-related costs are only one component of total O&S costs. The DDG-1000 design's total life-cycle O&S costs might be closer to the DDG-51 design's total life-cycle O&S costs than might be suggested by a comparison of crew-related costs only. In addition, future DDG-51s can be built to a modified design that could reduce their crew size from roughly 300 to something closer to 200, reducing the differential in crew-related costs between the DDG-1000 and DDG-51 designs.

- The two DDG-1000s already procured are enough to mature and demonstrate the DDG-1000 technologies that the Navy wants to use on the CG(X) cruiser and other future Navy surface ships. Procuring additional DDG-51s would reopen the production line for the DDG-51 hull design, which might serve as the basis for the CG(X) design.

Technical Risk

Over the past few years, GAO has reported on the technical risks involved in developing the several significant new technologies that are to be incorporated into the DDG-1000. The Navy over the years has worked to retire these risks. GAO reported in March 2008 that:

Three of 12 DDG 1000 critical technologies are fully mature, having been demonstrated in a sea environment. While 7 other technologies are approaching full maturity, 5 of them will not demonstrate full maturity until after installation on the ship. Two technologies remain at lower levels of maturity — the volume search radar and total ship computing environment. Land-based testing of a volume search radar prototype is expected to begin in May 2008 — a delay of over 12 months since last year's assessment. Software development for the total ship computing environment has been replanned, shifting functionality to later software blocks. The Navy plans on completing 85 percent of the ship's detail design prior to the start of construction....

The volume search and multifunction radars constitute the dual band radar system. While the multifunction radar has been tested at sea, the volume search radar continues to experience delays. Problems in developing the prototype and constructing the test facility have delayed land-based testing of the volume search radar by over a year. In order to support the ship construction schedule, the Navy has begun initial testing at an alternate test site. Because of issues with a critical circuit technology, the volume search radar will not demonstrate full power output until at least 2010 — after production of the dual band radar is well under way. Problems or delays discovered during testing will likely affect radar production and installation.

The total ship computing environment includes hardware and six blocks of software code. Current software development is focused on the fourth block. The Navy has reduced its software development efforts in order to accommodate available funding. As a consequence, some functionality has been deferred to blocks five and six. The Navy believes that cost and schedule parameters will still be achieved by leveraging non-development items and existing software code. However, full maturity will not occur until after the start of ship construction.

Of the seven technologies approaching full maturity, the Navy expects to demonstrate full maturity of the integrated deckhouse and peripheral vertical launch system by the start of ship construction in July 2008. Production of a large-scale deckhouse test unit is under way and final validation of the vertical launching system will occur in spring 2008. Practical limitations prevent the Navy from fully demonstrating all critical technologies at sea prior to ship installation. Testing of other technologies continues through ship construction start.

Due to scheduling issues for the lead ships, the Navy did not have time to fully test the integrated power system prior to shipyard delivery and instead requested funds in fiscal year 2008 to procure an additional unit. The Navy will conduct integrated power system testing in 2010 using this unit at a land-based test site. Considerable software development remains and land-based testing will mark the first integrated testing between the power generation and distribution system and the control system. If problems are discovered during testing, construction plans and costs could be at risk because the power systems needed for the first two ships will already have been delivered to the shipyards.

The Navy continues to test prototypes of the ship's hull form to demonstrate stability in extreme sea conditions at higher speeds. According to Navy officials, existing computer simulation tools over-predicted the ship's tendency to capsize. The Navy is now relying on testing of scale models in tanks

> and on the Chesapeake Bay, and is updating its computer simulation tool. Ongoing testing is aimed at developing guidance for operating the ship safely under different sea conditions.[22]

As individual DDG-1000 technologies mature, technical risk in the DDG-1000 program will shift more to the follow-on task of system integration — of getting all ship's technologies to work together smoothly in a single platform. In past defense acquisition programs, system integration has often proven to be at least as challenging as the task of developing individual new technologies.

As mentioned in the Background Section, the Navy since September 30, 2005, has been acting as the system integrator for the DDG-1000 program. Problems in the execution of the Coast Guard Deepwater program[23] and the Littoral Combat Ship (LCS) program led to a reexamination in Congress in 2007 of the concept of the private-sector lead system integrator (LSI), and to a desire among some Members to shift certain acquisition functions, including system design and integration, from the private sector, to where they had migrated starting in the 1990s, back to the federal government. The Navy's decision in 2005 to begin acting as the system integrator for the DDG-1000 program will make the program an early test of DOD's ability to once again perform the system-integration function following the downsizing of DOD's technical and acquisition workforce that occurred when acquisition functions were earlier transferred to the private sector. The DDG-1000 program, in addition to being an early test of DOD's abilities in this area, may represent a fairly challenging test, given the number of significant new technologies that are to be integrated into the ship.

In discussing the system-integration task, Navy officials argue that the DDG-1000 program office has the authority and resources to access technical capacity throughout the Navy, including expertise at Navy research, development, and testing centers in various parts of the country. Navy officials also argue that the engineering development models (EDMs) that it has used to develop key technologies for the DDG-1000 have been designed not only to develop the ability of each technology to work as a stand-alone item, but also to integrate well with other systems when installed on the ship. Navy officials also argue that since its beginning in the 1980s, the Navy has been responsible for managing a large number of contractors who make various components of the DDG-51 (including the Aegis combat system) that are then provided by the Navy to the shipbuilders as government-furnished equipment (GFE). By comparison, Navy officials argue, the task of overseeing the integration of the DDG-100 combat system will require the Navy to work with only two contractors (Raytheon and BAE).[24]

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[22] Government Accountability Office, *Defense Acquisitions[:] Assessments of Selected Weapon Programs*, GAO-08-467SP, March 2008, pp. 69-70.

[23] For additional discussion of the Deepwater program, see CRS Report RL33753, *Coast Guard Deepwater Program: Background, Oversight Issues, and Options for Congress*, by Ronald O'Rourke.

[24] Source: Navy briefing to CRS and CBO on April 10, 2008.

Industrial Base

The Navy's 30-year shipbuilding plan calls for procuring an average of about 1.5 DDG-1000s/CG(X)s over the next 17 years. If affordability considerations limit DDG-1000/CG(X) procurement to one ship per year in FY2011 and subsequent years, the average workload over time for the cruiser-destroyer industrial base in those years might thus be reduced by roughly one-third from levels that would be achieved under the Navy's 30-year plan.

The Navy informed CRS on March 11, 2008, that a DDG-1000 would require, by Navy estimates, about 2.5 times as much shipyard labor to build as would be required to build a DDG-51.[25] On April 10, 2008, the Navy clarified that this ratio was based on the number of labor hours that the Navy estimates will be needed to build the first two DDG-1000s, and that subsequent DDG-1000s would require smaller amounts of shipyard labor, reducing the ratio for subsequent ships to something less than 2.5 to 1.[26] (The DDG-51 design, in contrast, is already well down its learning curve and would not decline by a substantial additional amount through additional production.) Assuming a rate of learning in the DDG-1000 production process that might be typical for a complex combatant ship, and taking into account the shared production arrangement for the DDG-1000, a seventh DDG-1000 might require roughly 1.7 to 1.9 times as much shipyard labor to build as a DDG-51, and a class of seven DDG-1000s might require roughly 2 to 2.2 times as much shipyard labor to build as a group of seven DDG-51s.[27]

The Navy has stated that procuring additional DDG-51s would pose some production-line uncertainties regarding DDG-51 sub-vendors.[28]

Options for Congress

List of Potential Options

Potential options for Congress for the DDG-1000 program, some of which could be combined, include but are not limited to the following:

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[25] Source: Navy Office of Legislative Affairs telephone call to CRS on March 11, 2008.

[26] Source: Navy briefing to CRS and CBO on April 10, 2008.

[27] Source: CRS calculation based on a CRS assumption of:
— a smooth learning curve of 85% to 90% for the DDG-1000 program;
— a unified learning curve for the portions of every DDG-1000 that are to be built by only one single firm; and
— a split learning curve for the portion of each DDG-1000 that is to be built by the yard performing the final-assembly work on the ship.
For a discussion of shipbuilding learning curves, see CRS Report 96-785 F, *Navy Major Shipbuilding Programs and Shipbuilders: Issues and Options for Congress*, by Ronald O'Rourke, pp. 95-110. [out of print and available directly from the author]

[28] Source: Testimony of Navy officials before Seapower subcommittee of Senate Armed Services Committee on April 8, 2008.

- approve the seven-ship DDG-1000 program as proposed by the Navy;
- use a block-buy contract for DDG-1000s procured during the five-year period FY2009-FY2013;
- establish terms and conditions for the acquisition strategy to be used for the third and subsequent ships in the program;
- defer procurement of the third and/or subsequent DDG-1000s and use the funding programmed for that ship/those ships to instead procure other Navy ships;
- to help accelerate CG(X) procurement, procure three CG(X)s in FY2011, FY2012, and FY2013 in lieu of the fifth, sixth, and seventh DDG-1000s;
- as an annual affordability measure, limit DDG-1000/CG(X) procurement to a combined total of no more than one ship per year;
- as total-program affordability measure, limit DDG-1000/CG(X) procurement to a combined total of 11 or 12 ships (one for each of 11 or 12 planned carrier strike groups (CSGs));
- procure no more than two DDG-1000s for use as technology demonstrators for future surface combatants (and also as operational warships), and supplement the industrial base with other work; and
- start design work now on a lower-cost naval gunfire support ship and/or a lower-cost cruiser-destroyer, and start procuring these ships, rather than additional DDG-1000s or CG(X)s, when these new designs are ready for procurement.

With regard to the final option above, for additional discussion of potential lower-cost ships, see **Appendix C**.

Deferring DDG-1000s and Procuring Other Ships Instead

As mentioned in the "Introduction" section, at a February 27, 2008, hearing on Navy shipbuilding programs before the Defense subcommittee of the House Appropriations Committee, the chairman of the subcommittee, Representative John Murtha, stated that the subcommittee is considering deferring procurement of the third DDG-1000 and using the funding programmed for that ship to instead procure three other ships for the Navy in FY2009 — a San Antonio (LPD-17) class amphibious ship and two Lewis and Clark (TAKE-1) class dry cargo ships.

As also mentioned in the "Introduction" section, at a March 6, 2008, hearing on the Department of the Navy's proposed FY2009 budget before the House Armed Services Committee, certain committee members, including Representative Gene Taylor, the chairman of the Seapower and Expeditionary Forces subcommittee, stated

that they are considering the option of not procuring additional DDG-1000s and instead procuring additional Arleigh Burke (DDG-51) class Aegis destroyers. These DDG-51s, it was stated at the hearing, could act as a bridge to a design for the Navy's planned CG(X) cruiser that is based on an enlarged version of the DDG-51 hull and powered by one-half of the reactor plant that the Navy has designed for its new Ford (CVN-78) class nuclear-powered aircraft carriers.

With regard to the option of procuring additional DDG-51s instead of additional DDG-1000s, two variations might be envisaged. One would use the funding programmed for the third through seventh DDG-1000s to procure additional DDG-51s. The other would use the funding programmed for the third and fourth DDG-1000s to procure additional DDG-51s, and the funding for the fifth through seventh DDG-1000s to procure CG(X)s currently planned for procurement in later years, so as to accelerate the introduction of CG(X)s into the fleet.

As shown in **Table 2**, a total of $12,661 million is programmed in FY2009-FY2013 for the procurement of the third through seventh DDG-1000s.[29] As mentioned earlier, the Navy has testified in 2008 that a single additional DDG-51 might cost about $2.1 billion to procure, and that two additional DDG-51s might require about $3.3 billion to procure.[30] Based on the two-ship DDG-51 procurement cost figure, a total of $12,661 million might procure about 7.7 DDG-51s.

A total of $5,217 million is programmed in FY2009 and FY2010 for the procurement of the third and fourth DDG-1000s.[31] Again based on the Navy's cost estimate for procuring two DDG-51s, a total of $5,217 million might procure about 3.2 DDG-51s.

As mentioned earlier in the section on DDG-1000 affordability and cost-effectiveness, and discussed in more detail in **Appendix B**, the DDG-1000 and DDG-51 are both multimission destroyers, but they have somewhat different mission emphases. The DDG-1000 design features a stronger emphasis on land-attack operations and operations in littoral waters. The DDG-51 design is more oriented toward blue-water operations. Consistent with its larger size, higher procurement cost, and greater use of new technologies, the Navy believes the DDG-1000 is more capable than the DDG-51 design in several respects. Under the option discussed here, the greater individual capability of the DDG-1000 design in certain respects would be offset to some degree by the greater quantity of DDG-51s.

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[29] This figure excludes outfitting and post-delivery costs and $150 million in FY2008 advance procurement funding for the third DDG-1000.

[30] Source: Spoken testimony of Navy officials at April 8, 2008, hearing before the Seapower subcommittee of the Senate Armed Services Committee.

[31] This figure excludes outfitting and post-delivery costs, $150 million in FY2008 advance procurement funding for the third DDG-1000, and $51 million in FY2010 advance procurement funding programmed for the fifth DDG-1000.

Procuring three DDG-51s might provide 69% to 75% as much shipyard labor as procuring two DDG-1000s, and procuring eight DDG-51s might provide 78% to 86% as much shipyard labor as procuring five DDG-1000s.[32]

Procuring DDG-51s instead of DDG-1000s could increase work for supplier firms that provide materials and components for DDG-51s but not DDG-1000s, and reduce work for supplier firms that provide materials and components for DDG-1000s but not DDG-51s. The Navy states that procuring additional DDG-51s would pose some production-line uncertainties regarding DDG-51 sub-vendors.[33]

For additional arguments relating to the issue of procuring DDG-51s rather than DDG-1000s, see the earlier section on DDG-1000 affordability and cost-effectiveness.

The DDG-51s procured under this option could be built to a modified design with improved warfighting capabilities. The option of building DDG-51s to a modified design has been discussed in CRS reports since 1994.[34] Building DDG-51s to a modified design could affect the ships' procurement cost and increase the technology and cost risks associated with their procurement.

FY2009 Legislative Activity

The Navy's proposed FY2009 budget was submitted to Congress in early February 2009.

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[32] Source: CRS calculation based on Navy statement to CRS of March 11, 2008, as further clarified by Navy statement to CRS on April 10, 2008, that each of the first two DDG-1000s would require about 2.5 times as much shipyard labor to build as would be required to build a DDG-51, and further based a CRS assumption of:
— a smooth learning curve of 85% to 90% for the DDG-1000 program;
— a unified learning curve for the portions of every DDG-1000 that are to be built by only one single firm; and
— a split learning curve for the portion of each DDG-1000 that is to be built by the yard performing the final-assembly work on the ship.
For a discussion of shipbuilding learning curves, see CRS Report 96-785 F, *Navy Major Shipbuilding Programs and Shipbuilders: Issues and Options for Congress*, by Ronald O'Rourke, pp. 95-110. [out of print and available directly from the author]

[33] Source: Testimony of Navy officials before Seapower subcommittee of Senate Armed Services Committee on April 8, 2008.

[34] A 1994 CRS report presented the option of building DDG-51s to a lengthened configuration with a total of 128 VLS cells, as opposed to the 96 on the current Flight IIA DDG-51 design. (See CRS Report 94-343 F, *Navy DDG-51 Destroyer Procurement Rate: Issues and Options for Congress*, by Ronald O'Rourke, pp. CRS-27 to CRS-28. [out of print; available directly from the author]) In more recent years, CRS has presented the option of building a ship based on a lengthened version of the DDG-51 hull, with a displacement of about 11,000 tons, as one possibility for a potential lower-cost cruiser-destroyer design. See, for example, **Appendix C**.

Appendix A. DDG-1000 Mission Requirements

The DDG-1000's capabilities reflect an Operational Requirements Document (ORD) for the DDG-1000 that was approved by the Joint Staff of DOD in February 2004. Key performance parameters included in this document include having two AGSs that can each fire 10 rounds per minute, for a total of 20 rounds per minute.[35] DOD stated in 2005 that

> During the restructuring of the DD-21 program into the DD(X) program, the Navy re-evaluated each DD-21 Key Performance Parameter (KPP) to determine the potential for minimizing the size of the ship and ultimately the cost. The Navy made many adjustments and the resulting DD(X) KPPs represent the Navy's minimum requirements. No other known alternative meets all of the DD(X) KPPs and provide the sustained, precision, long-range naval surface fire support that the United States Marine Corps requires.[36]

Some observers speculate that the Navy and DOD established requirements for the DDG-1000 without a full appreciation of how large and expensive a ship design the requirements would generate. Naval analyst Norman Friedman, the author of numerous books on U.S. warship designs, stated in a 2004 book on U.S. destroyer designs that

> In past [Navy ship design] practice, the naval policymakers in OpNav [the Office of the Chief of Naval Operations] would write a draft set of [ship] characteristics.... The Preliminary Design branch of BuShips [the Bureau of Ships] or NAVSEA [the Naval Sea Systems Command] would develop sketch designs to meet the requirements. Often the OpNav policymakers would find the results outrageous — for example, exorbitantly expensive. Such results would force them to decide just how important their various requests had been. Eventually Preliminary Design would produce something OpNav found acceptable, but that might not actually be built....
>
> In contrast to past practice, no preliminary design [for the DDG-1000] was drawn up to test the cost of various requirements. Each requirement was justified in operational terms, (e.g., a level of stealth that would reduce detectability by some percentage); but those sponsoring the ship had no way of knowing the impact that a particular combination of such requirements would have. Normally NAVSEA would have created a series of sketch designs for exactly that purpose.[37]

An August 2005 trade press article suggested that growth in DD-21/DDG-1000 requirements (and cost) over time may have been related to the disestablishment of a Navy ship-design board called the Ship Characteristics Improvement Board (SCIB)

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[35] Statement by The Honorable Kenneth J. Krieg, Under Secretary of Defense (Acquisition, Technology and Logistics), Before the Subcommittee on Projection Forces, House Armed Services Committee, United States House of Representatives, July, 19, 2005, p. 2.

[36] Ibid, pp. 6-7.

[37] Norman Friedman, *U.S. Destroyers, An Illustrated Design History, Revised Edition*. Annapolis, Naval Institute Press, 2004, pp. 437 and 447-448. Punctuation as in the original.

— an entity that Admiral Michael Mullen, who became the Chief of Naval Operations on July 22, 2005, reestablished under a new name:

> Adm. Michael Mullen, the chief of naval operations, has directed the Navy to re-establish a high-level panel to closely monitor and control the requirements and configurations of new ships in a bid to rein in the skyrocketing cost of new vessel procurement.
>
> Adm. Robert Willard, vice chief of naval operations, is leading the effort as part of a larger undertaking to draw up alternative options for the Navy's current shipbuilding program....
>
> In essence, sources said, Mullen is looking to reconstitute the Ship Characteristics Improvement Board, which eventually became inactive in 2002. For more than 100 years, the Navy has maintained a high-level group of officials to advise service leaders on ship design and configuration. This group, established in 1900 as the General Board has gone through many name changes, including the Ship Characteristics and Improvement Board in the early 1980s and, until 2002, the Ship Characteristics and Improvement Panel.
>
> Navy officials say that the panel's oversight began to wane in the late 1990s, just as the DD-21 program — originally envisioned as a $750 million replacement for Spruance-class destroyers — took off, before becoming officially inactive in 2002. Requirements during this time were added to the new destroyer program, some of which raised eyebrows in the Navy, such as the need for a flag officer quarters. No other ship in that class has accommodations for an admiral. Still, the DDG-1000 has come to be regarded as a technology carrier for future surface ships and the price tag has ballooned to $3 billion a copy.
>
> Mullen's goal, spelled out in a July 25 memo to Willard and provided to *InsideDefense.com*, is to put in place a "process that adequately defines warship requirements and manages changes to those requirements (e.g. Ship Characteristics Improvement Board) in a disciplined manner, with cost and configuration control as the paramount considerations."...
>
> A recent RAND study conducted at the request of Mullen's predecessor, retired Adm. Vern Clark, concluded that a key cause for climbing ship costs is the number of requirements tacked on to a program, according to a consultant familiar with the findings of the study, which has not been made public.
>
> "So, what I think Mullen has in the back of his head is, 'I've got to get the requirements process for ships back under control or we're always going to end up, every time we talk about a new destroyer, with a $3 billion ship,'" said a former senior Navy official.
>
> This senior official, who was in a key Pentagon position as the DD-21 program commenced, said that without a panel overseeing the ship's configuration and true requirements the new destroyer program became weighed down with capabilities that carried a high price tag.
>
> "In hindsight, we realized that we had put requirements on the ship that no one had really vetted for its cost impact on the ship. For example, it was to

> operate acoustically silent and risk free in minefields," said the official. "If the SCIB had existed, this probably would not have happened."[38]

A March 2007 report from the Center for Strategic and Budgetary Assessments (CSBA) made a similar point:

> For nearly a century, the Navy's SCIB — a group of high-ranking DoN [Department of the Navy] officials — worked to balance desired warship warfighting requirements against their impact on a ship's final design and production costs. The primary reason why the Navy lost cost control over the DD-21/DD(X)/DDG-1000 was that just as the ship entered its design definition phase, the power of the Navy's SCIB was waning, replaced by a Joint requirements definition process with no fiscal checks and balances.[39]

Some observers, such as Norman Friedman, have raised questions about the Navy's decision to use a tumblehome (i.e., inward-sloping) hull for the DDG-1000. A 2006 magazine article by Friedman, for example,

- raised questions about the implications of a tumblehome hull for the ship's ability to deal with underwater damage;[40]
- asked whether the Navy knew at the outset of the DDG-1000 design process how much a decision to incorporate a tumblehome hull (and other survivability features) would increase the size of the ship; and
- questioned whether the reduced visibility of the tumblehome hull to certain types of radars — the central reason for using a tumblehome hull — will be negated by its visibility to high-frequency (HF) surface wave radars that are now for sale on the international market.

The article, which refers to the DDG-1000 by the previous designation DD(X), stated:

> In the case of the DD(X), the overriding requirement [in determining the hull design] was to minimise radar cross section — stealth. Much of the hull design was dictated by the attempt to reflect radar pulses away from the radar emitting them, so that radar returns would be minimised. By now the main technique is well known: slope all flat surfaces and eliminate the corner reflector created by the juncture of the hull and water....

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[38] Jason Sherman, "Mullen To Bring Back Panel To Control Ship Configuration, Cost," *Inside the Navy*, August 8, 2005.

[39] Robert Work, *Know When To Hold 'Em, Know When To Fold 'Em: Thinking About Navy Plans For The Future Surface Battle Line*, Washington, Center For Strategic and Budgetary Assessments, 2007. p. 6. (CSBA Backgrounder, March 7, 2007).

[40] Other observers have also expressed concerns about the stability of the DDG-1000's tumblehome hull in certain see conditions. For a discussion, see Christopher P. Cavas, "Is New U.S. Destroyer Unstable?," *DefenseNews.com*, April 2, 2007.

If the ship could be stabilized sufficiently [against rolling from side to side], then she would never (or almost never) present any vertical surfaces [to a radar]. In the case of DD(X), stabilization is apparently achieved using ballast tanks. Such tanks in turn demand internal volume deep in the ship. Overall, stealth demands that as much as possible of the overall volume of the ship be buried in her hull, where the shape of the ship can minimise radar returns. That is why, paradoxically, a carefully-designed stealthy ship will be considerably larger — for more internal volume — than a less stealthy and more conventional equivalent. In the case of DD(X), there were also demands for improved survivability. The demand for stealth implied that anti-ship missiles were the most important envisaged threat. They hit above water, so an important survivability feature would be to put as much of the ship's vitals as possible below water — which meant greater demands for underwater volume....

Once the tumblehome hull had been chosen, [the ship's designers] were apparently also constrained to slope the bow back [creating a surface-piercing or ram bow] instead of, as is usual, forward....

There were numerous reasons why [past] naval architects abandoned tumblehome hulls and ram bows. Tumblehome reduces a ship's ability to deal with underwater damage. When a conventional flared (outward-sloping) hull sinks deeper in the water, its waterplane area [the cross-section of the ship where it intersects the plane of the water] increases. It becomes somewhat more stable, and it takes more water to sink it deeper into the water. Because the waterplane area of a tumblehome ship *decreases* as it draws more water, such a ship is easier to sink deeper. Tumblehome also apparently makes a ship less stable, and hence less capable of resisting extreme weather conditions. The larger the ship, the more extreme the weather has to be to make that critical. Critics of DD(X) have concentrated on the danger; defenders have concentrated on how extreme the critical weather condition would be.

In the end, whether the DD(X) hull form is attractive depends on an evaluation of anti-radar stealth as a design driver. About a decade ago, the DD(X) design concept was sold on the basis of a lengthy (and, incidentally, unclassified) analysis, the gist of which was that a heavily-armed surface combatant could play a decisive role in a Korean scenario...

The key analytic point... was that it would be very important for the ship to come reasonably close to enemy shores unobserved. That in turn meant anti-radar stealth. However, it soon came to mean a particular kind of anti-radar performance, against centimetric-wave radars [radars with wavelengths on the order of centimeters] of the sort used by patrol aircraft (the ship would fire [its weapons] from beyond the usual horizons of shore-based radars). As it happens, anti-ship missiles use much the same kinds of radars as patrolling aircraft, so it could be argued that the same anti-radar techniques would be effective in the end-game in which missiles would approach the ship....

Without access to files of the time, it is impossible to say whether those approving the [DDG-1000] project realised that its stealth and survivability characteristics would produce a 14,000 to 17,000 ton destroyer. About the same time that DD(X) characteristics (requirements) were being approved, the decision was taken at [the] Defense Department (not Navy) level that there would be no internal feasibility design. In the past, the feasibility stage had the very useful role of showing those setting requirements what their implications would be. At

the very least, the Navy's senior leadership would have been given warning that they would have to justify a drastic jump in destroyer size when they wanted to build DD(X). That jump might well have been considered justified, but on the other hand the leadership might also have asked whether a somewhat less dramatic approach would have been acceptable.

About a decade after the requirements were chosen, with DD(X) well advanced, the situation with regard to stealth may be changing. Shaping is relevant only at relatively short [radar] wavelengths. For about a quarter-century, there has been talk of HF surface wave radars, which operate at wavelengths of about 10 to 200 meters — i.e. at wavelengths the size of a ship. Canada currently operates this type of radar, made by Raytheon, for surveillance of the Grand Banks; another is being tested in the Caribbean. Australia has bought this kind of radar to fill gaps in over-the-horizon radar coverage. Turkey is buying such radars for sale for some years. In 2005 it was reported unofficially that China had bought [a] Russian HF surface wave radar the previous year.

It seems almost certain that HF surface wave radar can defeat any kind of stealth shaping designed primarily to deal with shorter-wave[length] radars. Moreover, [HF surface wave] radars have an inherent maximum range (due to the way they operate) of about 180nm.... At long range [the radar's beam] is not nearly accurate enough to aim a missile. However, we can easily imagine a netted system which would use the long-range [HF surface wave] radar to define a small box within which the target ship would be. A missile with GPS [Global Positioning System] guidance could be flown to that box, ordered to search it....

If the argument given here is realistic, then the considerable sacrifices inherent in the DD(X) design no longer seem nearly as attractive. It can still be argued that a design like the DD(X) is attractive well out to sea, beyond the reach of coastal radars. In that case, however, there may be other signatures which can be exploited. For example, ships proceeding at any speed create massive wakes.... it is clear that the wake produces a radar return very visible from an airplane or, probably, from a space-based radar....

In the end, then, how much is stealth worth? As a way of avoiding detection altogether, probably less than imagined. That leaves the rather important end-game, the hope being that decoys of some sort greatly exceed actual ship radar cross-section. That is probably not a foolish hope, but it does not require the sort of treatment reflected in [the] DD(X).

Now, it may be that the Untied States typically faces countries which have not had the sense to buy anti-stealth radars (though we would hate to bet on that). In that case, DD(X) may well be effectively invisible to them. So will a lot of less thoroughly stealthy ships.[41]

Potential oversight questions for Congress include the following:

- **SCIB and DDG-1000 requirements.** Are the DDG-1000's requirements partly a result of inadequate discipline, following the

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[41] Norman Friedman, "The New Shape of Ships," Naval Forces, No. II, 2006: 56-58, 60, 62-63. Italics as in the original. Friedman makes somewhat similar comments in chapter 17 (pages 431-450) of *U.S. Destroyers, An Illustrated Design History, Revised Edition*, op cit.

disestablishment of the SCIB, in the Navy's process for setting requirements for new ships? If the SCIB had remained in existence during the DD-21/DDG-1000 design process, which of the DDG-1000's current requirements would have been reduced or eliminated?

- **Tumblehome hull.** How much did the decision to use a tumblehome hull (and other survivability features) increase the size and cost of the DDG-1000? In the mid-1990s, when design work began on the ship now known as DDG-1000, how well did the Navy understand the relationship between using a tumblehome hull and ship size and cost? What effect does the tumblehome hull have on the DDG-1000's ability to deal with underwater damage? To what degree will HF surface wave radars negate the stealth characteristics of the DDG-1000 design?

- **AGSs.** Since the DDG-1000 is the only ship planned to carry AGSs, and since AGSs are viewed by the Marine Corps as necessary to meet Marine Corps requirements for naval surface fire support capability, should the AGSs be considered the most-critical payload element on the DDG-1000, and certain other payload elements, though desirable, be considered as possibly less critical by comparison?

Appendix B. Comparison of DDG-1000 and DDG-51 Capabilities

This appendix provides information on capabilities of the DDG-1000 and DDG-51 designs, as presented by the Navy on three occasions:

- in Navy testimony before the Projection Forces subcommittee of the House Armed Services Committee on July 19, 2005;
- at a Navy briefing to CRS on June 10, 2005; and
- at a Navy briefing to CRS and CBO on April 10, 2008.

Overview. The DDG-1000 and DDG-51 are both multimission destroyers, but they have somewhat different mission emphases. The DDG-1000 design features a stronger emphasis on land-attack operations and operations in littoral waters. The DDG-51 design is more oriented toward blue-water operations.

Consistent with its larger size, higher procurement cost, and greater use of new technologies, the DDG-1000, the Navy believes, is more capable than the DDG-51 design in several respects. The Navy states that it designed the DDG-1000 for "full-spectrum littoral dominance" and believes the DDG-1000 would be considerably more capable than the DDG-51 in littoral operations. The Navy believes that because of its reduced signatures, defensive systems, number of gun shells in its magazine, and ability to resupply gun shells while underway, the DDG-1000 would have considerably more capability than the DDG-51 to enter defended littoral waters and conduct sustained operations there. The Navy believes that because of its guns, aviation capabilities, special operations forces (SOF) support capabilities, and small-boat capabilities, the DDG-1000 would be able to perform more littoral missions than the DDG-51. The Navy believes that because of its radars and C4I/networking capabilities, replacing a DDG-51 with a DDG-1000 in a carrier strike group would increase the strike group's anti-air warfare (AAW) capabilities by about 20%. The Navy believes that because of differences in their sonar capabilities, the DDG-51 has more blue-water anti-submarine warfare (ASW) capability than the DDG-1000.

Navy Testimony at July 19-20, 2005 Hearing. At the July 19 portion of a July 19-20, 2005, hearing before the Projection Forces subcommittee of the House Armed Services Committee, Navy officials testified that, compared to the DDG-51 design, the DDG-1000 design's capability improvements include, among other things,

- a threefold improvement in capability against anti-ship cruise missiles, including significantly better radar performance in situations involving near-land radar clutter;
- a 10-fold improvement in overall battle force defense capability, in part because of a 5-fold improvement in networking bandwidth capacity;

- 15% more capability to defend against group attacks by enemy surface craft (i.e., "swarm boats");
- a 50-fold improvement (i.e., reduction) in radar cross-section, which dramatically enhances survivability and reduces by half the total number of missiles that need to be fired in an intercept engagement;
- a 10-fold increase in operating area against mines in shallow-water regions;
- three times as much naval surface fire support capability, including an ability to answer 90% of Marine Corps calls for fire within five minutes, permitting the ship to meet stated Marine Corps firepower requirements — a capability otherwise unavailable in the surface fleet — giving the ship a capability roughly equivalent to one-half of an artillery battalion, and permitting a 65% reduction in Marine Corps artillery;
- a ship design that allows underway replenishment of gun shells, creating the equivalent of an almost-infinite ammunition magazine and permitting nearly continuous fire support;
- almost 10 times as much electrical capacity available for ship equipment, giving the ship an ability to support future electromagnetic rail guns and high-energy laser weapons; and
- features such as an automated fire-suppression system, peripheral vertical launch system, and integrated fight-through-damage power system that significantly increase ship survivability.[42]

June 10, 2005, Navy Briefing to CRS. The following comparison of DDG-1000 and DDG-51 capabilities is based on information provided by the Navy to CRS at a briefing on June 1, 2005. The information has been updated in some places to account for changes since 2005.

Growth Margin. The DDG-51 and DDG-1000 designs each have about a 10% growth margin. For the roughly 9,000-ton DDG-51, this equates to about 900 tons of growth margin, while for the 14,987-ton DDG-1000, this equates to about 1,400 tons of growth margin.

Ship Mobility. The two designs are roughly equivalent in terms of maximum sustained speed, cruising endurance, and seakeeping (i.e., stability in rough seas).

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[42] Source: Points taken from Statement of Admiral Vern Clark, U.S. Navy, Chief of Naval Operations, Before The House Armed Services Committee Projection Forces Subcommittee, July 19th, 2005, and Statement of The Honorable John J. Young, Jr., Assistant Secretary of the Navy (Research, Development and Acquisition), and RADM Charles S. Hamilton, II, Program Executive Officer For Ships, Before the Projection Forces Subcommittee of the House Armed Services Committee on DD(X) Shipbuilding Program, July 19, 2005.

The DDG-1000's draft (28 feet) is somewhat less than the DDG-51's (31 feet). Other things held equal, this might give the DDG-1000 an ability to operate in (or be berthed at) places where the water depth is sufficient for the DDG-1000 but not for the DDG-51. The DDG-1000's length (600 feet) is greater than the DDG-51's (505 feet). Other things held equal, this might give the DDG-51 an ability to be berthed in spaces that are long enough for the DDG-51 but not for the DDG-1000.

Electrical Power for Weapons and Systems. The DDG-51 has 7.5 megawatts (MW) of electrical power for its weapon systems, while the DDG-1000 design, with its integrated electric-drive system, can provide up to 78 MW for its weapons and power systems by diverting power from propulsion to weapons and systems.

Signatures and Detectability. The DDG-1000 has a smaller radar cross-section and lower infrared, acoustic, and magnetic signatures than the DDG-51. The two designs are roughly equivalent in terms of the detectability of their radar and other electromagnetic emissions. The DDG-1000's reduced signatures, DDG-1000 supporters, will make the DDG-1000 harder to detect, localize, classify, and target, giving the DDG-1000 a significant advantage in engagements against enemy forces.

Survivability and Damage Control. The Navy states that the DDG-1000 would be able to keep fighting after an attack like the one that disabled the USS Cole (DDG-67) on October 12, 2000.

The two designs are roughly equivalent in terms of degree of compartmentalization and ship stability when flooded. The DDG-1000's vertical launch system (VLS) is more heavily armored than the DDG-51's. The DDG's fire-suppression system is automated only in the engine room and magazine, while the DDG-1000's system is automated throughout the ship, making it safer and more effective. The DDG-51's flood-control system is not automated, while the DDG-1000's is, which the Navy believes will make it more effective. The DDG-1000's electrical power distribution system is an "integrated fight-through" system, meaning that it is designed to automatically isolate damaged areas and reroute electrical power around them. All critical DDG-1000 systems are dual-fed, meaning that if power from one source is cut off, it can be routed through a second source. The DDG-51's electrical power distribution system lacks these features.

C4I/Networking Bandwidth. The C4I[43] and networking systems on the DDG-1000 would have five times as much bandwidth as those on the DDG-51. The C4I/networking capability of the DDG-1000 is equivalent to that on the LHD-8 amphibious assault ship. In addition to improved warfighting capability, this increased bandwidth would provide sailors aboard the DDG-1000 a better ability to "reach back" to information sources ashore when conducting at-sea maintenance of shipboard equipment, potentially increasing the availability rates of shipboard equipment.

[43] C4I stands for command and control, communications, computers, and intelligence.

Flag-Level Command Facilities. The DDG-1000 has facilities for embarking and supporting a flag-level officer and his staff, so that they could use the ship as platform for commanding a group of ships. The DDG-51 does not have such facilities.

Anti-Air Warfare/Ballistic Missile Defense (AAW/BMD). The radars on the two ships are roughly equivalent in terms of dB gain (sensitivity) and target resolution. The firm track range of the DDG-1000's dual-band radar — the range at which it can maintain firm tracks on targets — is 25% greater for most target types than the firm track range of the DDG-51's SPY-1 radar. The DDG-1000's AAW combat system would be able to maintain about 10 times as many tracks as the DDG-51's Aegis system. The DDG-1000's radar has much more capability for resisting enemy electronic countermeasures and for detecting targets amidst littoral "clutter." As a result of the better performance amidst littoral clutter, the Navy believes that ships escorted by the DDG-1000 in defended littoral waters would have three times as much survivability as ships escorted by the DDG-51.

The two designs would use the same types of area-defense and point-defense interceptor missiles. They would also use the same flares, chaff, and decoys to confuse enemy anti-ship cruise missiles, but the Navy believes these devices would be more effective on the DDG-1000 because of the DDG-1000's reduced signatures.

Anti-Surface Warfare/Strike Warfare. The DDG-1000 would have considerably more naval surface fire support (NSFS) capability than the DDG-51. The DDG-51 has one 5-inch gun, while the DDG-1000 has two 155mm Advanced Gun Systems (AGSs). The DDG-51's gun can fire an initial salvo of 20 rounds per minute and can subsequently fire at a sustained rate of four rounds per minute (20/4). The DDG-1000's two guns have a combined firing rate of 20/20. The shells currently fired by the DDG-51's gun have a range of 13 nm. Future shells are to have a range of up to 50 nm. The shells to be fired by the DDG-1000's guns are to have a range of 63 to 74 nm, and consequently could cover (at 74 nm) more than three times as much area ashore (assuming a 25 nm standoff from shore) as a shell with a range of 50 nm. The shells fired by the DDG-51 carry 8 pounds of explosive, while those fired by the DDG-1000 are to carry 24 pounds of explosive. When fired at less than maximum range, the shells fired by the DDG-1000 can alter their flight paths so that six to eight of them can hit a target at the same time; the shells to be fired by the DDG-51 do not have this capability. The DDG-51 carries 600 of the 13nm-range shells or 230 of 62nm-range shells, while the DDG-1000 carries a total of 600 of its shells. It might be possible to fit the DDG-51 with one of the 155mm guns to be carried by the DDG-1000; it would likely require the removal of both the DDG-51's 5-inch gun and its forward (32-cell) VLS. In this configuration, the DDG-51 might carry about 120 of the gun's 155mm shells.

The 155mm guns on the DDG-1000 could be replaced in the future with an electromagnetic rail gun or directed-energy weapon. The DDG-51 does not have enough electrical power to support such weapons.

Antisubmarine Warfare (ASW). The DDG-51's sonar system is more capable for blue-water ASW operations, while the DDG-1000's system is more capable for littoral ASW operations. The DDG-1000's bow-mounted sonar and

towed array can interact to more rapidly triangulate targets. The Flight IIA DDG-51 lacks a towed array. The DDG-1000's radar would have more capability than the DDG-51's radar for detecting submarine periscopes.

The DDG-51 has six torpedo tubes for firing lightweight (12.75-inch diameter) anti-submarine torpedoes, while the DDG-1000 has none, but the Navy does not believe these tubes to be of significant operational value against potential future threats. Both ships can launch lightweight torpedoes from their helicopters or fire the Vertical Launch Antisubmarine Rocket (VLA), which is armed with a lightweight torpedo.

The ships would use the same countermeasures for confusing enemy torpedoes, but the Navy believes these countermeasures would be more effective on the DDG-1000 because of the DDG-1000's reduced signatures.

Mine Warfare (MIW). The DDG-1000's bow-mounted sonar includes an in-stride mine-avoidance capability; the DDG-51's sonar suite has less capability for detecting mines. The DDG-51 can be built to a design that permits the ship to embark and operate the Remote Minehunting System (RMS); six ships in the DDG-51 program (DDGs 91 to 96) have been built to this design. The Navy says that the DDG-1000's reduced acoustic and magnetic signatures would translate into a significantly greater operating area in mined waters.

Missiles for Performing Above Missions. The DDG-51 has 90 missile-launching tubes in its VLS, while the DDG-1000 has 80. The DDG-51's VLS tubes can accommodate a missile up to 21 inches in diameter, 21 feet in length, and about 3,000 pounds in weight. The DDG-1000's VLS tubes can accommodate a missile up to 24 inches in diameter, 22 feet in length, and about 4,000 pounds in weight. The gas-management (i.e., heat-management) system of the DDG-1000's VLS tubes can accommodate a hotter-burning missile than the gas-management system of the DDG-51's VLS, so the DDG-1000 might be more capable of using future missiles if they are hotter-burning.

Aviation for Performing Above Missions. The DDG-51 can embark and operate two SH-60 helicopters but does not have electronics for launching and recovering unmanned aerial vehicles (UAVs). The DDG-1000 can embark, operate, and provide full maintenance for two SH-60 helicopters or one SH-60 helicopter and three UAVs. The DDG-1000's flight deck is larger than the DDG-51's and can accommodate all joint rotary-wing aircraft, including the MV-22, the CH-53, and the H-47. The DDG-1000's flight deck is 10 feet higher off the water and can therefore be used for full flight operations in a sea state (i.e., sea condition) that is at least one step higher (i.e., rougher) than is possible for the flight deck on the DDG-51.

Special Operations Forces (SOF) Support. The DDG-1000 has additional berthing for 20 SOF personnel (i.e., a platoon), as well as a space for SOF mission planning and spaces for stowing SOF gear. The DDG-51 lacks these features.

Boats. The DDG-51 can embark two seven-meter boats that are deployed and recovered with a davit. The DDG-1000 can embark two 11-meter boats and four

rubber raiding craft that are deployed and recovered with a stern ramp, which permits faster and safer launching and recovering, and launch/recovery operations in higher sea states.

Habitability Features for Crew. On the DDG-51, enlisted crew berthing spaces accommodate 20 to 60 sailors each. On the DDG-1000, every sailor would have a stateroom, and each stateroom would accommodate four sailors. The Navy believes these features would improve crew quality of life, which can improve retention rates.

April 10, 2008 Navy Briefing to CRS and CBO. At an April 10, 2008 briefing to CRS and CBO, Navy officials presented a briefing slide providing a comparison of the DDG-1000 design's capabilities relative to the DDG-51 design's capabilities. The briefing slide is reprinted below (with some editing changes for readability) as **Table 3**.

In addition to the information presented in **Table 3**, another slide in the Navy briefing stated that the DDG-1000's radar cross section will be similar to that of a fishing boat.[44] Navy officials have also stated separately that the DDG-1000's acoustic signature will be similar, at certain speeds, to that of certain U.S. Navy submarines.[45]

In elaborating on the point in **Table 3** pertaining to the DDG-1000's electrical power, Navy officials stated at the briefing that at a speed of 20 knots, the DDG-1000 would have 58 megawatts of power available for powering non-propulsion shipboard systems. The briefing stated that the DDG-51, by comparison, has 7.5 megawatts of power available for non-propulsion systems.

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[44] Navy briefing slide #8, entitled "Zumwalt Advantage," in Navy briefing to CRS and CBO, April 10, 2008.

[45] Source: Spoken testimony of Navy officials at hearing before Seapower subcommittee of Senate Armed Services Committee on April 8, 2008.

Table 3. DDG-1000 Capabilities Relative to DDG-51 Capabilities

Item	DDG-1000 compared to DDG-51
Radar cross section	Significantly smaller
Ship detectability by threat aircraft	Threat must fly lower and closer to detect the ship
Firm track range on enemy anti-ship cruise missiles	Significant improvement, especially in land-clutter environments
Performance against small boat swarm raids	Engage small boats at 3 times the effective range and engage 10 times more threats
Safe operating area in areas with enemy bottom mines	Significantly larger
Land attack capability	3 times as much lethality and 40% greater range than Extended Range Guided Munition (ERGM)[a]
Manning	50% less crew
Electrical power	Sufficient capacity for rail gun, laser weapons, and future radar upgrades

Source: Navy briefing slide #7, entitled "Multi-Mission Combatant," in Navy briefing to CRS and CBO, April 10, 2008. CRS has edited the words in the table to make them easier to understand.

a. ERGM was a 5-inch extended-range guided munition for the 5-inch guns on Navy cruisers and destroyers. The Navy in 2008 canceled development of ERGM.

Appendix C. Potential Lower-Cost Ships

Lower-Cost Gunfire Support Ship. CBO and naval analyst Robert Work of the Center for Strategic and Budgetary Assessments (CSBA) have both suggested, as a lower-cost naval gunfire support ship, an AGS-equipped version of the basic hull design of the San Antonio (LPD-17) class amphibious landing ship. Such a ship might begin procurement in FY2009, following procurement of a final "regular" LPD-17 amphibious landing ship in FY2008. CBO estimates that an initial AGS-armed LPD-17 might cost about $1.9 billion, including $400 million detailed design and nonrecurring engineering costs, and that subsequent ships might cost about $1.5 billion each.[46]

Lower-Cost Cruiser-Destroyer. A new-design, lower-cost cruiser-destroyer might:

- start procurement as soon as FY2011, if design work were started right away;
- incorporate many of the same technologies now being developed for the DDG-1000 and CG(X);
- employ a modular, "plug-and-fight" approach to some of its weapon systems, like the LCS;
- be similar to the DDG-1000 and CG(X) in terms of using a reduced-size crew reduce annual operation and support costs;
- use a second-generation surface combatant integrated electric-drive propulsion system that is smaller and lighter than the first-generation system to be installed in the first DDG-1000s;[47]
- carry a payload — a combination of sensors, weapon launchers, weapons, and aircraft — that is smaller than that of the DDG-1000 or CG(X), but still sizeable; and
- be built in one or two variants — an air- and missile-defense version to replace the CG(X), which would preserve CG(X) radar capabilities while reducing other payload elements, and possibly also a surface fire support version to supplement the DDG-1000, which

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[46] See Congressional Budget Office, *Options for the Navy's Future Fleet*, May 2006, pp. 56-57 (Box 3-1).

[47] The integrated electric-drive system to be installed in the first DDG-1000s uses advanced induction motors. A second-generation system could use smaller and lighter motors and generators that employ permanent magnet or high-temperature superconducting technology. Both of these technologies are currently being developed. For more on these technologies, see CRS Report RL30622, *Electric-Drive Propulsion for U.S. Navy Ships: Background and Issues for Congress*, by Ronald O'Rourke. (July 31, 2000)

would preserve the DDG-1000's two AGSs while reducing other payload elements.

Notional options for a lower-cost cruiser-destroyer include, but are not limited to, the following:

- a ship displacing about 9,000 tons — about the same size as the DDG-51; or

- a ship displacing about 11,000 tons — about 25% less than the DDG-1000's displacement of about 14,500 tons, about the same size as the nuclear-powered cruisers procured for the Navy in the 1960s and 1970s, and about 1,800 tons larger than the DDG-51.

Such a ship might be based on either the DDG-51 hull design, which is a conventional flared hull that slopes outward as it rises up from the waterline, [48] or a new flared hull design, or a reduced-sized version of the DDG-1000's tumblehome (inwardly sloping) hull design.

The Navy in 2002 identified the following ship-design characteristics as items that, if varied, would lead to DDG-1000 concept designs of varying sizes, capabilities, and procurement costs:

- cruising range,
- maximum sustained speed,
- number of Advanced Gun Systems (AGSs) and AGS shells,
- hangar space for helicopters and UAVs,
- undersea warfare systems (i.e., sonars and mine countermeasures systems), and
- numbers and types of boats for special operations forces.

Using these variables, the Navy in 2002 developed notional DDG-1000 concept designs with estimated full load displacements ranging from 12,200 tons to about 16,900 tons. One of the concept designs, with an estimated full load displacement of about 12,700 tons, included 32 Advanced Vertical Launch System (AVLS) cells (rather than the DDG-1000's 80), two AGSs (like the DDG-1000), 600 AGS shells (like the DDG-1000), a maximum sustained speed a few knots lower than the DDG-1000's, and a helicopter flight deck smaller than the DDG-1000's. Another concept design, with an estimated full load displacement of about 12,200 tons, included 64 AVLS cells, 1 AGS, 450 AGS rounds, a maximum sustained speed a few knots lower than the DDG-1000's, and helicopter flight deck smaller than the DDG-1000's.

The Navy in 2003 developed another set of notional DDG-1000 concept designs with estimated full load displacements ranging from 11,400 tons to 17,500 tons. One of the concept designs, with an estimated full load displacement of 13,400 tons,

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[48] Using the DDG-51 hull in its current dimensions might produce a ship of about 9,000 tons; lengthening the DDG-51 hull with a mid-hull plug might produce a ship of about 11,000 tons.

included 64 AVLS cells, 1 AGS, and 450 AGS rounds. Another concept design, with an estimated full load displacement of 11,400 tons, included 32 AVLS cells, 1 AGS, and 300 AGS rounds.

The 2002 and 2003 notional DDG-1000 concept designs with displacements of less than 14,000 tons appear to have preserved other DDG-1000 features, such as the wave-piercing, tumblehome hull, the integrated electric drive system (though with reduced total power in at least some cases), the total ship computing environment, the autonomic fire-suppression system and other features permitting a reduced-sized crew, the DDG-1000 radar suite, the hull and towed-array sonars, medium-caliber guns for use against surface targets, and a helicopter hangar (though not necessarily as large a hangar as on the DDG-1000).

Reducing payload features a bit more than under the smallest of the 2002 and 2003 notional concept designs might lead to a design with a displacement of about 9,000 to 11,000 tons. The Navy has viewed designs of less than 14,000 tons as unsatisfactory because of their reduced individual capabilities. It is not clear, however, to what degree the Navy's assessment of such designs also takes into account the difference that size (and thus unit procurement cost) can have on the total number of ships that might be procured within available resources, and consequently on future cruiser-destroyer force levels. Total cruiser-destroyer force capability is dependent on both cruiser-destroyer unit capability and the total number of cruisers and destroyers.

Notional Procurement Profiles With Lower-Cost Ships. **Table 4** and **Table 5** show notional procurement profiles incorporating the ships described above. In **Table 4**, an AGS-equipped version of the basic LPD-17 hull design is procured to supplement the Navy's DDG-1000s, and an air- and missile-defense version of the smaller cruiser-destroyer is procured starting in FY2011 in lieu of the CG(X). In **Table 5**, a smaller cruiser-destroyer in two versions — an AGS-equipped version to supplement the Navy's DDG-1000s, and air- and missile-defense version in lieu of the CG(X) — is procured starting in FY2011.

Table 4. Alternative with LPD (AGS) and Smaller Cruiser-Destroyer

(annual quantities procured, FY2007-FY2021)

	07	08	09	10	11	12	13-21	Total
DDG-1000	2[a]	0[a]	1	1				4
LPD (AGS)[b]			1	1	1	2		5
SCD[c]					1		2/year	19

Source: Prepared by CRS.
a. Each of the two ships to be procured in FY2007 is to be split-funded across FY2007 and FY2008.
b. Basic LPD-17 hull equipped with 2 Advanced Gun Systems (AGSs).
c. Air- and missile-defense version of smaller cruiser-destroyer (SCD), in lieu of CG(X).

Table 5. Alternative with Smaller Cruiser-Destroyer
(annual quantities procured, FY2007-FY2022)

	07	08	09	10	11	12	13-22	Total
DDG-1000	2[a]	0[a]	1	1		1		5
SCD[b]					1		2/year	21[b]

Source: Prepared by CRS.
a. Each of the two ships to be procured in FY2007 is to be split-funded across FY2007 and FY2008.
b. Includes 2 AGS-equipped versions of smaller cruiser-destroyer (SCD), for a total (along with 5 DDG-1000s) of 7 AGS-equipped ships, and 19 air- and missile-defense versions, in lieu of CG(X).

CSBA Report Recommendations. A March 2007 report from the Center for Strategic and Budgetary Assessments (CSBA) on the Navy's surface combatant force discusses existing and future Navy surface combatants and makes the following recommendations (emphasis as in the original):

> **— First, "fold" the CG-21 hand: cancel all planned new CG-21s [i.e., DDG-1000s and CG(X)s] beyond the two DDG-1000s already authorized.**[49] A variation of this plan would be to build just one ship. By building two (or one) operational test beds/technology demonstrators, the Navy can recoup most of the previous "bets" made on the CG-21s. Having one or two test ships would allow further testing and refinement of the SPY-3 multifunction radar, which is to be installed on future aircraft carriers regardless of what happens with the DDG-1000, and perhaps on other ships. Over time, the ships could be modified to test other future surface combatant combat systems such as underwater combat systems or electronic warfare systems. Regardless of configuration, the ships would provide the battle fleet with a test article for new integrated power system components as well as electrically-powered weapons. In this role, the less capable advanced induction motor to be installed on the first two DDG-1000s ships will be as effective as the permanent magnet motor — the Navy's desired electric motor. The ships' larger VLS cells would allow the Navy to test larger diameter guided missiles. In fleet exercises, the ships would help to identify the true operational payoffs of ship stealth within the context of distributed naval battle networks. Finally, these large ships with small crews would help the Navy to refine the maintenance concepts for future optimally manned fleet combatants (i.e., warships with reduced crews).
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> **— Second, "hold" the Aegis/VLS fleet: design a comprehensive, Aegis/VLS Battle Network Reliability and Maintenance (BNRAM) program, with the goal of producing the maximum number of interchangeable, Interim Large Battle Network Combatants. (I-LBNCs).** The Navy's ultimate goal is to shift to a new Large Battle Network Combatant, or LBNC — a far better description of future Total Force Battle Network [TFBN] ships-of-the-line than the multimission guided-missile "cruisers" and "destroyers" or general-purpose "destroyers" associated with today's legacy Total Ship Battle Force. Until they can be designed, betting an additional $10-15 billion on five or six additional DDG-1000s would appear to provide far less of a TFBN payoff than making a similar sized or even smaller bet on a well-thought-out and executed BNRAM program to convert the 84 programmed Aegis/VLS warships into more powerful

[49] The CSBA report uses the term CG-21s to refer collectively to DDG-1000s and CG(X)s.

I-LBNCs. This conversion program would be patterned after earlier modernization and conversion efforts, like the Fleet Reliability and Maintenance (FRAM) program, which converted many of the large legacy fleet of World War II destroyers into effective Cold War ASW escorts. The BNRAM would include a thorough mid-life upgrade to the ships' hull, machinery and electrical (HM&E) systems; a combat systems upgrade to allow the ships to counter emerging threats; and a battle network upgrade to allow the ships to operate as part of a coherent naval battle network. Consistent with battle network precepts, the intent of the BNRAM would be to bring as many ships as possible to a common I-LBNC combat system baseline. The BNRAM would also aim to lower substantially the operations and maintenance costs (O&M) costs necessary to operate the legacy Aegis/VLS fleet, in order to save money in the near term, and to offset to some degree the added costs necessary to keep older ships in service over the longer term. A key part of this effort centers on reducing the crew size needed to operate, maintain, and fight the ships. Importantly, because this effort can justifiably be seen as converting legacy Aegis/VLS ships into more capable I-LBNCs, the BNRAM should be funded out of more stable Ship Construction Navy (SCN) funds rather than the more volatile O&M accounts.

— Third, immediately kick-start a clean-sheet competition to develop and design a family of next-generation Large Battle Network Combatants, with close oversight by the newly reconstituted Ship Characteristics Improvement Board (SCIB). For nearly a century, the Navy's SCIB — a group of high-ranking DoN [Department of the Navy] officials — worked to balance desired warship warfighting requirements against their impact on a ship's final design and production costs. The primary reason why the Navy lost cost control over the DD-21/DD(X)/DDG-1000 was that just as the ship entered its design definition phase, the power of the Navy's SCIB was waning, replaced by a Joint requirements definition process with no fiscal checks and balances. One of the first things Admiral Mike Mullen, the current Chief of Naval Operations, did upon assuming his office was to reconstitute the Navy's SCIB. With a chance to start from a clean sheet of paper, naval design architects could leverage an additional decade of experience in the post-Cold War era to design an entirely new family of next-generation LBNCs, under the close oversight of the newly reconstituted SCIB. These new warships would have a common gas turbine or perhaps even a nuclear power plant that supplies enormous shipboard electrical generating capacity; common electric propulsion motors; common integrated power systems that distribute electric power to the ships' electric motors, combat systems, and weapons, as needed; and advanced automation to enable them to operate with relatively small crews. Their single common hulls, or network frames, should be large and easily produced, based on the best ideas of naval engineers, with an affordable degree of stealth. The network frames would be able to accept a range of open architecture battle network mission modules consisting of sensors and onboard and offboard weapons designed explicitly to support a battle network rapid capability improvement strategy. The cost-constrained goal for the combination of network frames and network mission modules would be to build new LBNCs at a rate of five every two years, allowing the complete transition from 84 Aegis/VLS I-LBNCs to 88 next-generation LBNCs in 35 years. The ships would be built under a profits-related-to-offer arrangement. While each of the two remaining surface combatant shipyards could count on building one LBNC per year, they would compete for an extra ship every other year. The yard with the lowest bid would be able to claim higher profit margins on the two LBNCs it would build until the next bi-annual competition. In this way, in addition to the natural cost savings

due to learning curve efficiencies, the Navy would be able to spark continuous competition between the two building yards.

— Starting in FY 2008, build a minimum of seven additional [Arleigh] Burke-class DDGs [i.e., DDG-51s] to help sustain the industrial base until the new LBNC is ready for production. In effect, building one modified Burke each year between FYs 2008 and 2014 would replace the seven DDG-1000s in the current plan. For reasons that are detailed in the forthcoming report, the first four modified Burkes would be configured with the same Area Air Defense Command Capability System (AADCCS) found on the Ticonderoga-class CGs. In addition, all seven ships would serve as active test beds for DDG improvements identified as possible candidates for further BNRAM backfits, or to test next-generation LBNC technologies. As such, the ships would serve much the same purpose as both the Forrest Sherman-class destroyers — which helped to bridge the shipbuilding gap between World War II combatants and Cold War combatants designed to battle jets, missiles, and high-speed submarines — and modified legacy combatants like the USS Gyatt, DDG-1, which helped to illuminate the way forward toward a new generation of BFC combatants. Provided all went as planned, Congress would authorize two of the next-generation LBNCs in FY 2015, split funded as in the current arrangement for the DDG-1000, giving each of the two remaining surface combatant construction yards one ship. The general fleet-wide transition from Aegis/VLS I-LBNCs to the new LBNC design would then begin in FY 2017, with three ships authorized after a bidding competition. Of course, if the design was not ready for production, additional Burkes could be built until it was.

— Task each of the planning yards for CG and DDG modernization to design and implement a comprehensive follow-on maintenance regime to ensure all Aegis/VLS combatants are able to serve out the remainder of their 35-year service lives effectively. The Navy's plan counts on every one of the 84 programmed Aegis/VLS combatants of completing 35 years of commissioned service. Yet, since the end of World War II, few surface combatants remain in commission beyond 25-30 years of service — even after receiving mid-life upgrades. Unless the BNRAM program includes a sustained maintenance regime beyond its mid-life HM&E, combat systems, and battle network upgrades and crew reduction measures, it is unlikely the ships will see their 35th year. The building shipyards might be the logical organizations to implement this new maintenance regime on the Navy's behalf. By establishing financial incentives that provide the yards with bonuses for every year a ship stays in service beyond 25 years, the Navy will maximize the probability that the ships will remain in service. As part of their efforts, the yards and the Navy should also solicit ideas for further ship improvements from vendors, and complete the trade studies for an expanded service life extension program (SLEP) of the existing ships, with a goal of extending their expected service lives to 40 years. This would provide a hedge should design work on the next-generation LBNC be delayed for any reason, or if a future maritime challenge spurs the need to rapidly expand the number of large combatants beyond the 88 included in the 313-ship Navy.[50]

[50] Robert Work, *Know When To Hold 'Em, Know When To Fold 'Em: Thinking About Navy Plans For The Future Surface Battle Line*, Washington, Center For Strategic and Budgetary Assessments, 2007. pp. 5-8. (CSBA Backgrounder, March 7, 2007).